H-E-B Grocery Total Power Solution™ for Fuel Cell Powered Material Handling Equipment

PowerEdge™ Fuel Cell Hybrid Power Packs
PowerTap™ Hydrogen Refueling

Gus Block
Nuvera Fuel Cells, Inc.
5/13/2011

Project ID #
H2RA008

NUVERA FUEL CELLS

Overview

Timeline

- Project Start – 08/01/09
- Project End – 07/31/11
- Percent Complete: 79%
  (based on calendar time through March '11)

Barriers and Risks

- Operation of hydrogen and fuel cell equipment in very demanding application
- Confirming value proposition for fuel cells for material handling equipment
- Safety planning and safe operation

Budget

- Total Project Funding:
  - Overall: $3,324K
  - DOE: $1,139K
  - Cost share: $2,185K

Partners

- H-E-B Grocery – Host Site
- H-E-B Parkway Systems
- Airgas
- Nuvera Fuel Cells – Project Lead

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ARRA Relevance

Objective

Validate DOE market transformation activities by demonstrating:

- Fuel cell-powered forklifts operating in highly transient environments.
- A distributed natural gas-based hydrogen refilling system as a precursor to future automotive fuel cell refilling stations.

ARRA 2009 Relevance

- Stimulate use of emerging technologies – additional investment by H-E-B is anticipated, without ARRA funding.
- Develop jobs and job skills (manufacturing, product development, repair and maintenance) in clean energy growth industries.

FCT ARRA Relevance

- Project has led to improvements to make fuel cells and hydrogen refueling equipment commercially viable.

Barriers and Risks Addressed

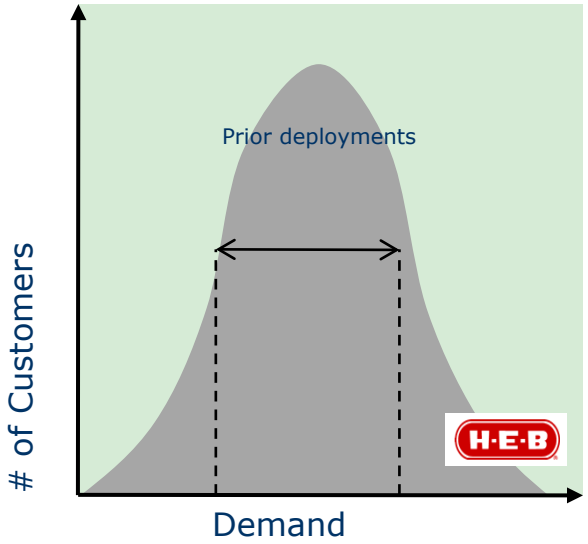
- Use of equipment in demanding customer application and environment has uncovered substantial opportunities to improve fuel cell and hydrogen technology reliability.
- Operation and maintenance costs are being quantified.
- Proper safety planning and safe operation of all equipment.

Approach

Demanding Application

- Class-II forklifts are generally the most demanding material handling application.
- H-E-B incentivizes forklift operators to maximize the amount of product moved.
- H-E-B has optimized warehouse utilization with higher lifts & heavier pallets.
- H-E-B facility poses challenges with air quality, shock & vibration, and high ambient temperatures.

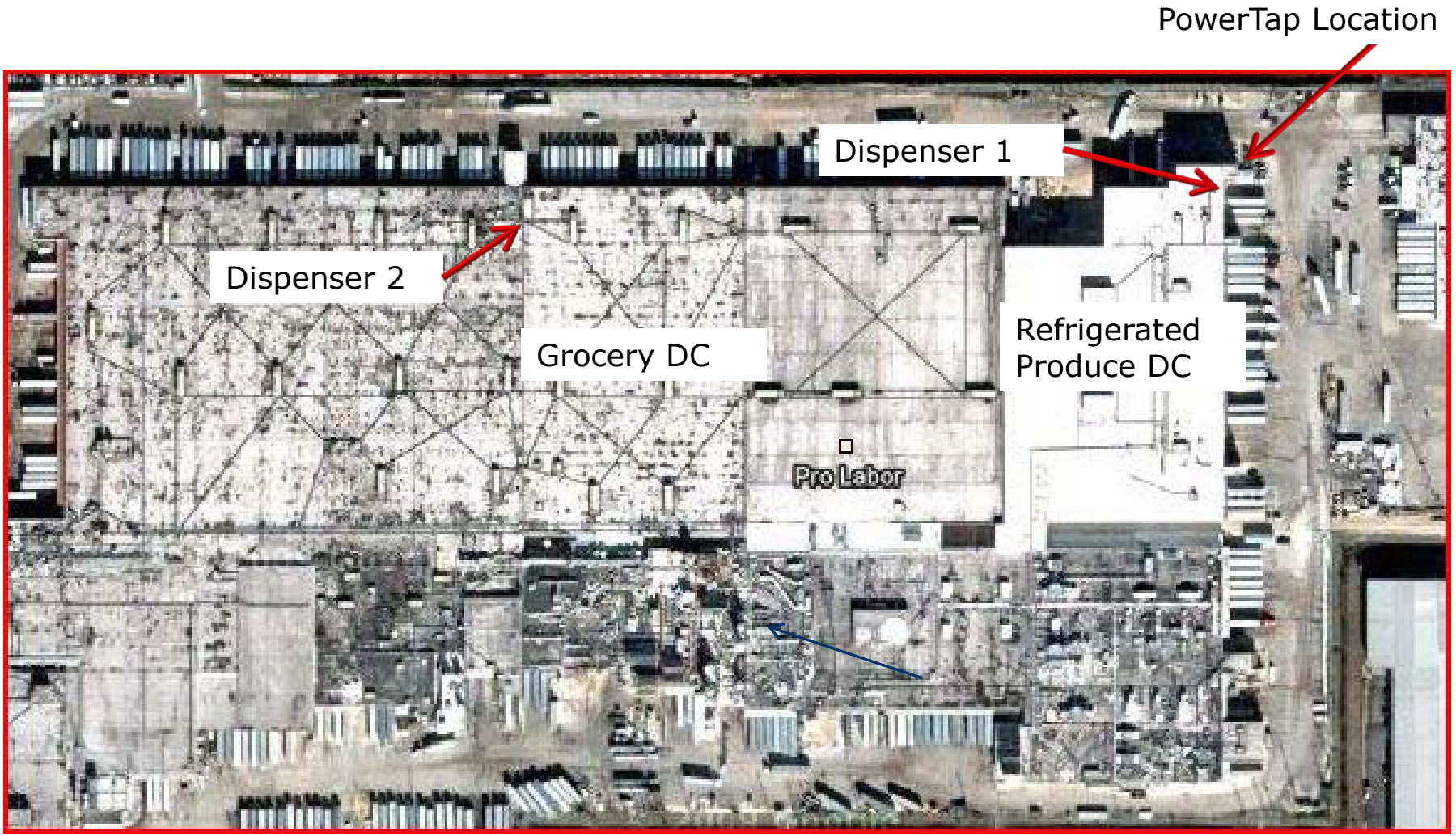
These factors resulted in challenges that emerged during the course of the project and were addressed in the previous 12 months.



Tasks and Status - Approach

ID	Task	Status
1	Build fuel cell systems and hydrogen generation and refueling station.	Complete (Q409)
2	Create site-specific service plan, including training of local service providers: • Parkway Systems (fuel cell systems) • Airgas (hydrogen infrastructure)	Complete (Q409)
3	Deploy fleet • 60 forklift operators received hydrogen and fuel cell training • Multiple issues resulted in scale-back of fleet July – November 2010 during reliability campaign	Complete (Q410)
4	Confirm value proposition • Initial productivity assessment completed Q110 • Follow-up underway with process excellence group • Go/No Go for fleet expansion will depend on trials with 2011 PowerEdge model RL40 (early summer 2011)	50% Complete (Q111)
5	Final Testing	0% Complete
6	Project management	79% Complete (Q111)

Site Plan - Approach

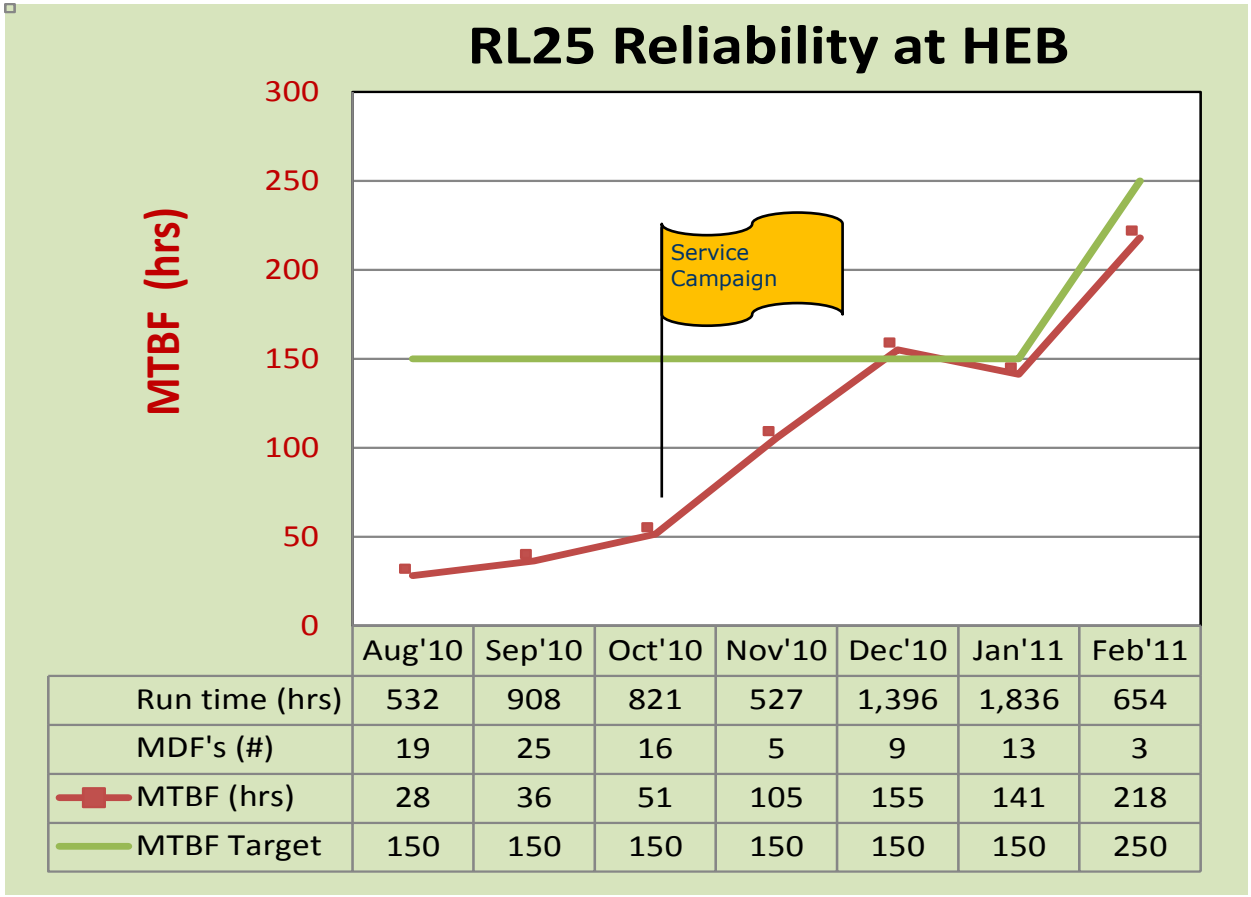


Technical Accomplishments and Progress

RL25 Issues

- Fleet was reduced from 14 to 4 units in July 2011
  - Root cause analysis undertaken
  - Corrective actions identified
  - Reliability campaign initiated
- Issues Resolved
  - ✓ Dirt
  - ✓ Shock & vibration
  - ✓ High temperatures
  - ✓ Short Absorbed Glass Mat battery life
- Performance verified during busy season
  - MTBF is 3-4X higher
- Test & validate future product enhancements
  - More robust power circuits
  - Auto-Start feature to extend battery life
  - Improved controls to extend stack life

Technical Accomplishments and Progress



	Aug'10	Sep'10	Oct'10	Nov'10	Dec'10	Jan'11	Feb'11
Run time (hrs)	532	908	821	527	1,396	1,836	654
MDF's (#)	19	25	16	5	9	13	3
MTBF (hrs)	28	36	51	105	155	141	218
MTBF Target	150	150	150	150	150	150	250

* Feb'11 data through 2/9/11

Mean Time Between Failure (MTBF) is 3-4 times higher in Dec'10 – Feb'11 vs. Aug – Oct'10

Technical Accomplishments and Progress

PowerTap Issues

- High ambient temperatures reduced hydrogen generator capacity, de-rated from 56 to 45 kg/day.
  - New cooling strategy will be implemented in Summer 2011.
- Power outages cause some electrical components to fail
  - Protections/replacements implemented on case-by-case-basis.
- Local natural gas composition and water quality require more frequent replacement of desulphurizing media and RO membranes.
- Water pump speed control not robust, so target steam pressure was not consistently achieved (Sep'10), requiring manual intervention every several days.
  - New control strategy being developed.

Technical Accomplishments and Progress

PowerTap Reliability

PowerTap has supplied >90% of all hydrogen consumed at H-E-B since Sep'10, and is at or near 100% currently.

Technical Accomplishments and Progress

Safety

- Safety Plan prepared in compliance with the DOE Safety Planning Guidance for Hydrogen Projects.
- Reviewed by and discussed DOE Hydrogen Safety Panel in December 2010 during on-site visit.
  - Focus was primarily on safety devices and design, especially on dispenser and dispenser area.
  - All recommendations will be reviewed and implemented as needed.
- Safety plan will be revised to respond to Panel comments.
  - More thorough description of the level of coordination between H-E-B and Nuvera on communication and management of near-misses, incidents and changes, was requested.

Technical Accomplishments and Progress

8 PowerEdge safety Near Misses or Non-Events identified to date.

Near Miss: An event that under slightly different circumstances could have become an Incident.

Example: Unplanned hydrogen release insufficient to sustain a flame.

Non-Event: A situation, occurrence, or other outcome relevant to safety that does not involve an Incident (Severity 1) or a Near-Miss (Severity 2).

Examples: Failed safety inspection, or an unsafe material condition beyond normal wear and tear, that if left uncorrected, could eventually compromise personal safety.

- 2 non-hydrogen fire Near Misses involving electrical interconnection and power management.
  Primary Factor: Design Flaw
- 3 water discharge Non-Events involving PowerEdge controls
  Primary Factor: Design Flaw
- 3 minor hydrogen releases (no ignition) Non-Events involving hydrogen tanks
  Primary Factor: Maintenance Required

Technical Accomplishments and Progress

4 PowerTap safety Incidents, Near Misses, or Non-Events identified to date.

Incident: An event that results in:

- *A lost time accident and/or injury to personnel*
- *Damage/unplanned downtime for project equipment, facilities, or property*
- *Impact to the public or environment*
- *Any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited*
- *Release of any volatile, hydrogen containing compound (other than HCs used as common fuels)*

- 1 20-gallon hydraulic oil leak Incident involving cyclic fatigue failure of un-supported cantilevered pressure gauge
  Primary Factor: Design Flaw
- 2 reformate release Near Misses from PTG-50 involving 1) damaged O-ring and 2) HX structural support
  Primary Factor: Design Flaws
- 1 Non-Event involving movement of hydrogen tubing on roof during sustained high winds (80 mph)
  Primary Factor: Weather

Technical Accomplishments and Progress

Corrective Actions for Safety Issues

PowerEdge

- Regen modules were upgraded to prevent the electrical shorting.
- Water management hardware and controls software were upgraded to eliminate the excess water discharges on the warehouse floor.

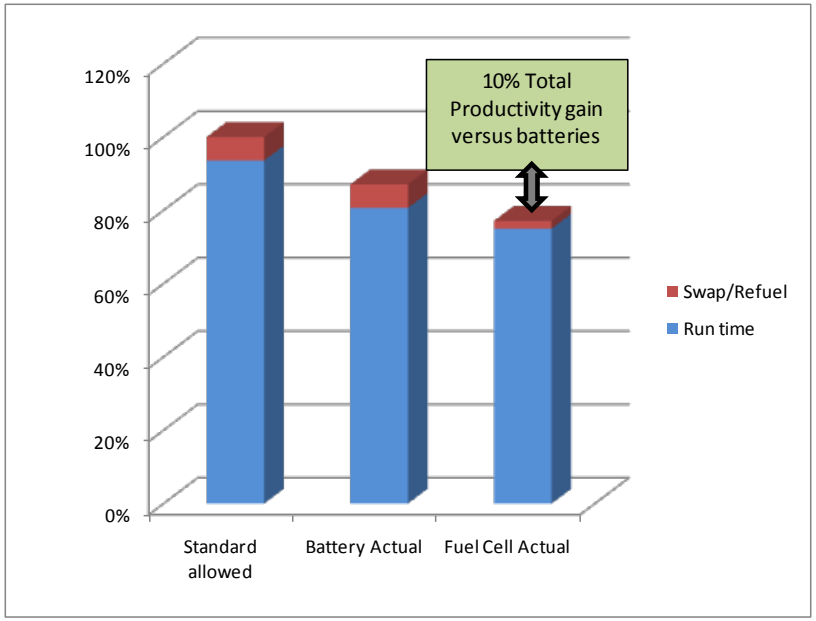
PowerTap

- PTC compressor was upgraded to ensure all components and gauges were adequately supported against vibration.
- Structural support for the HX in the PTG was upgraded to withstand thermal cycling.
- Service procedure for replacing the filter was updated to help reduce the risk of damaging O-rings.
- Supports for the high pressure tubing running along the warehouse roof to the dispensers were upgraded to withstand wind speeds up to 120 mph.

Technical Accomplishments and Progress

Value Proposition

- Cost of Ownership
  - Assessed on $/hour basis
    - Air & Water Filters
    - Battery repair & replacements
    - Stack and cell repair & replacements
    - Desulphurizing media
- Attempting to gather data regarding reduced truck maintenance
- Productivity
  - 10% total productivity gain vs. batteries measured in Q110
  - Will repeat in Q111



3 Month Average
January - March 2010

Service Plan - Collaboration

Nuvera Customer Care provides safety & service training, spare parts, data analysis, warranty, and factory service support.

- H-E-B Parkway Systems is Local Service Provider for PowerEdge fuel cell systems.
  - 1st Responder Role: Minimize customer downtime.
  - Tier-1 Service training
    - Operator training
    - Schedule maintenance
    - Basic diagnostics and repairs
  - Tier-2 Service qualification
    - Advanced qualification for safety critical repairs (high pressure/voltage).
- Nuvera is Local Service Provider for the PowerTap hydrogen refueling system.
  - Airgas Southwest personnel trained as LSPs but do not have sufficient resources to provide 24*7 service coverage.
  - Airgas SW will take over LSP role after fleet expansion (2 add'l PowerTaps).
- Airgas (Bozrah, CT)
  - Provides 24*7 monitoring of PowerTap status.

Future Work

- Continue to operate 14-unit fleet in normal operations to gain durability and life cycle cost information on the fuel cell systems.
- Monitor and record the long term operation cost of on-site hydrogen generation.
- Compile performance data of PowerEdge and PowerTap systems.
- Assess productivity gains.
- Undertake steps necessary for fleet expansion (28 PowerEdge systems and 2 PowerTap systems)
  - Field testing of higher-power RL40 PowerEdge units

Future Work – Fleet Expansion

Phase 1: One PowerTap hydrogen refueler, and 14 PowerEdge units in produce and grocery distribution centers.

Phase 2: One additional PowerTap systems and 16 more PowerEdge units, completing the conversion of produce and grocery DCs.

Phase 3: One additional PowerTap system and 12 PowerEdge freezer units.

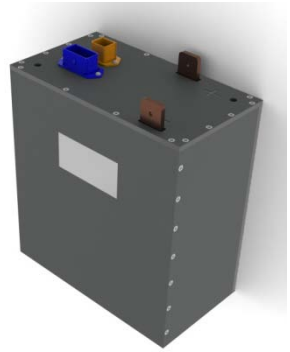
Phases 2 and 3 are beyond the project scope but are made possible because of the accomplishments of ARRA-funded Phase 1.

Future Work – Fleet Expansion

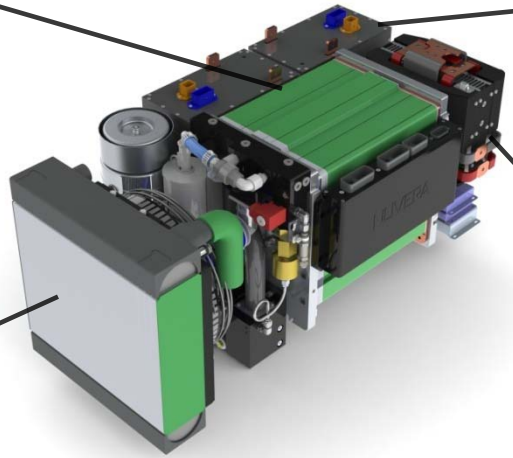
Go/No Go on Phase 2 depends on successful testing of higher-power PowerEdge RL40.

Product Enhancements

High Power XDS Stack



High Efficiency Li-Ion Battery



High Duty Thermal Management System

10kW Integrated Power Core

High Efficiency Digital DC/DC Converter

To ensure high performance and reliability, Nuvera is upgrading key sub-systems and utilizing a disciplined testing and qualification process.

Summary

- H-E-B's demanding operation has helped Nuvera understand how to develop a more robust product.
- Nuvera has incorporated all of these learnings into the design & controls of the products for Phase 2 for H-E-B as well as for future customers.
- H-E-B is realizing a significant productivity gain.
- Job creation:
  - 1 job associated with PowerTap maintenance
  - 2 jobs associated with PowerEdge maintenance
- Hydrogen infrastructure
  - On-site generation a unique feature of the project
  - Directly relevant to the establishment of automotive hydrogen infrastructure

Technical Back-Up Slides

PowerEdge Fuel Cell System

Product Specifications

	RL25
Rated Power (30 sec)	25 kW
Voltage	36 VDC
Operating Current Range[1]	-400A to 1150A
Energy Storage Capacity[2]	35.7 kWh
Size - in. (mm)	38.2 in. x 20.1 in. x 30.8 in. (970 mm x 510 mm x 781 mm)
Target Weight - lbs (kg)	2600 lbs (1155 kg)
Refueling Time	120 sec
Hydrogen Storage	1.0 kg
Hydrogen Pressure	5075 psig (350 bar)
Hydrogen Port	SAE J-2600 H35, CE 0036
Ambient Operating Temperature[3]	25 to 95°F (-4 to 35°C)
Environment	Indoor Use Only
Emissions	Water Vapor

Notes 1: Actual lower limit is dependent on truck upper voltage threshold (value shown based on 44V)
2: Based on LHV of H_2 at 5075 psi (350 bar), 15°C and 1 hr battery discharge rate
3: System must be stored and started above freezing conditions (4°C, 39°F minimum)

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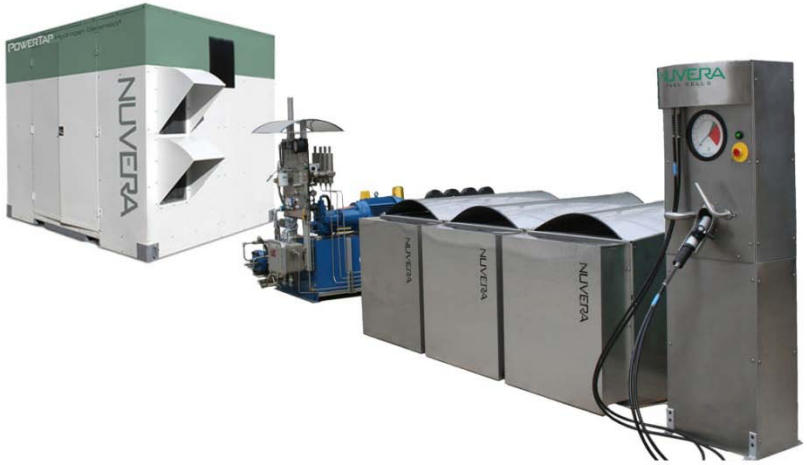
PowerTap Hydrogen Infrastructure



PowerTap Hydrogen Generator	Specifications
Rated Hydrogen Production	50 kg/day
Hydrogen Purity	99.995%
Natural Gas Consumption	7.5 MBTU/day 222 Nm^3/day
Water Consumption	2400 l/day
Electrical Consumption	9 kW average
Size	12 ft x 4 ft x 9 ft 3.66 m x 1.22 m x 2.74 m
Operating Temperature	-4°F to 104°F (-20°C to 40°C)
Standards Compliance	Designed for CSA, CE
Environment	Outdoor
Emissions[1]	NOx: <15 ppm CO: <50 ppm SOx: undetectable

PowerTap Hydrogen Station	Specifications
Gaseous Hydrogen Source	Steam reformer, electrolyzer or delivered via tube trailer or liquid hydrogen
Dispensing Rate	500 – 1000 gram/minute
Dispensing Pressure	5000 psig (350 bar)
Storage Capacity	Configurable from 12 – 128 kg
Compressor	Hydraulically driven intensifier
Electrical Consumption	12 kW average
Operating Temperature	-4°F to 104°F (-20°C to 40°C)
Standards Compliance	System Designed to: CSA HGV4 & NFPA 52 Dispenser Nozzle: SAE J2600-H35 Type A Compliant
Environment	Compression and Storage: Outdoor Dispenser: Indoor or Outdoor

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